CORRELATION BETWEEN ELECTRICAL MEASURED PARTIAL DISCHARGES AND ACOUSTIC EMISSION SIGNALS FROM NEW AND THERMAL AGED PRESSBOARDS IN OIL

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Abstract: The insulation in transformers especially large transformers mostly consists of pressboard and oil. Partial discharge is one of the main results of erosion and immature failure inside the insulation. Acoustic partial discharge detecting method has the advantage of possible detecting the partial discharge location beside it is not influenced by electrical noises. The aim of this paper is to find the parameters, which could influence the correlation between electrical partial discharge and acoustic emission signal, parameters such as the start level of acoustic emission at the specific partial discharge apparent charge, maximum and number of acoustic emission bursts during the specific time and average partial discharge apparent charges with two sensors (150 kHz and 75 kHz peak frequency) for different kinds of non-impregnated pressboards (new and aged) with different degree of polymerization. The test setup consists of needle-oil gap-pressboard and ground electrode, which were investigated for two pressboards. The effect of electrical partial discharge charges (induced charges) on acoustic emission frequency were evaluated by comparing the amplitude of acoustic emission signals measured with two sensors with different peak frequencies. According to these experiments it is shown that the amounts of acoustic emission signals for the same amount of partial discharge apparent charges for aged pressboard are higher than for new pressboard. One of the reasons of this fact could be the lower degree of polarization of aged pressboard compared to the new pressboard which causes stronger vibration created by electrical partial discharge signals and causes higher amplitude of acoustic emission signals.

1 INTRODUCTION
Power transformers are one of the major capital items, and the costs due to a failure, are high in both direct costs and downtime. The early detection of problems is essential in order to reduce losses due to failure. For this reason transformers are monitored frequently using a variety of methods. An important way for monitoring conditions of high voltage equipment is to measure partial discharge activities. Electrical, mechanical and thermal stresses increase the possibility of partial discharge (PD) in high voltage insulation materials and can cause failure in high voltage devices. A PD is a short release of current caused by the build-up of electric field intensity in a finite region, which results in a localized, instantaneous release of energy and causes several effects such as chemical, electrostatic, electromagnetic and acoustic. Electrical measuring system also known as conventional measuring system has been used for several decades to detect PDs in high voltage systems [1]. The acoustic (unconventional) method is one of the non-destructive diagnostic methods used to measure, detect and localize PD in power equipment. Another advantage of this method is immunity to electromagnetic interferences [2]. According to this fact the correlation between acoustic and electrical method has been taken into consideration.

2 EQUIPMENT AND TEST SETUP

2.1 Sensors and decoupling circuit

Two types of acoustic sensors (150 kHz and 75 kHz peak frequency) with 40 dB internal pre-amplifiers have been used in these measurements. The integral sensors are completely enclosed in a stainless steel case and coated to minimize RFI/EMI interference. In addition, care has been taken to thermally isolate the critical input stage of the pre-amplifier, in order to provide excellent temperature stability over the range of -45°C to +80°C. Figure 1 shows the acoustic emission (AE) sensors. Table 1 illustrates the specific characteristics of these sensors. To separate AE signals from DC signals a decoupling circuit has been used. Figure 2 shows the decoupling circuit with the possibility of energizing 4 AE sensors at the same time.
Figure 1: AE Sensors a) 150 kHz, b) 75 kHz.

Table 1: Information of acoustic sensors

<table>
<thead>
<tr>
<th>Frequency Range in kHz</th>
<th>Peak Frequency in kHz</th>
<th>Weight in gr</th>
<th>Case Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-400</td>
<td>150</td>
<td>70</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>30-120</td>
<td>75</td>
<td>157</td>
<td>Stainless steel</td>
</tr>
</tbody>
</table>

Figure 3: a) Hsu-Nielsen calibration pencil, b) Overall view of the transducer calibrated by the Hsu-Nielsen method, installed on a tank wall

2.3 Test setup

To evaluate the relation between acoustic emission signals and electrical partial discharge, a steel container has been used. The size of the steel container is 80 cm × 40 cm × 30 cm and it filled up with transformer oil (Shell Diala S2 ZU-I). A needle with tip radius of about 40 µm was used as shown in figure 4.

2.2 Hsu-Nielsen calibration method

Hsu Nielsen method was developed at the 1980s as one of the pulse calibration methods [4]. This method is easy to use and based on producing a signal due to break graphite pin of pencil and the similarity of this signal to AE signal. The calibration pencil consists of an automatic pencil, marking points of 2H hardness and the gauge of 0.5 mm. In this method should be ensured that the graphite pin pulled out about 3 mm and the angle of pencil is same for all calibration procedures. Figure 3 shows the pencil and the way of using this method on the sample tank.

Figure 4: Schematic view of the needle
Figure 5 shows container, pressboard, sensors and needle-plane arrangements.

Figure 5: Arrangement of the tank, needle-plane, pressboard and sensors

2.4 Measuring devices

A physical acoustic digital signal processing (DSP) device µSAMOS for getting the acoustic signals and an ICM electrical PD measuring device for evaluating the electrical PD signals were used. Figure 6 shows these two different devices.

Figure 6: a) Physical acoustic µSAMOS system [5], b) Electrical PD measuring system (ICM).

3 TEST PROCEDURE

To evaluate the correlation between electrical and acoustic effect of PD the following procedure has been applied. First of all, sensors were covered by silicone gel in order to get wave perfectly, then they were mounted on tank wall, sensors were connected to oscilloscope and µSAMOS measuring system by BNC cable in order to get acoustic signals at the same time. In the next step, ICM measuring system was installed in order to measure electrical PD apparent charge simultaneously with acoustic method. Finally, the applied high voltage on the needle was increased step by step in order to create PD at different charges inside the new and 700 hours thermal aged non-impregnated pressboards. All of these measurements have been done at room temperature where the distance between needle (the source of PD) and the AE sensors mounted on the body of the sample tank was 40 cm. Figure 7 shows new and thermal aged pressboards with their dimensions.

Thermal aging has a direct effect on the degree of polarization (DP) of the papers and pressboards. The DP is used as a diagnostic tool to determine the condition of the transformers [6]. The DP value for non-impregnated new and thermal aged pressboard were 1130 and 358.

The measuring time duration considered always 1 minute.

Figure 7: a) different kind of pressboards b) dimensions of the pressboards

4 RESULTS

4.1 Maximum AE amplitude in dB

The maximum amplitude in dB of the acoustic signals for different acoustic sensors and pressboards (new and aged) in 1 minute at 100 pC average electrical charge was evaluated. Figure 8 shows the results for these two different sensors.

It can be revealed that thermal aged pressboard has higher maximum AE signals at the same amount of average electrical PD apparent charge compare to the new one, which could be due to lower damping of acoustic signals or higher vibration in thermal aged pressboard compared to new pressboard.
Figure 8: Maximum amplitude in dB of the acoustic signals measured by two different sensors in new and aged pressboards at 100 pC average electrical PD apparent charge

4.2 AE inception PD

The lowest charge of PD needed to get AE signals more than maximum level of acoustic noises, which was in this experiment considered as 40 dB is named AE inception PD.

According to this definition AE inception PD depends on several parameters such as the experiment arrangement, environment noise and the sensitivity of the AE sensors, but it could be used to compare the effect of PD electrical charges on AE signals at the same arrangement, sensors and environment acoustic noise.

The results show that AE inception PD for non-impregnated new and thermal aged pressboards measured by 150 kHz AE sensor are 70 pC and 40 pC, which shows better acoustic detection from thermal aged pressboard.

4.3 Number of AE Bursts (AEB)

AE Burst (AEB) is a group of AE oscillations that constitutes a transient signal and has a length of about 140 µs from the first threshold crossing to last one [7]. The numbers of AE bursts measured by DSP µSAMOS within 1 minute at 150 pC average electrical PD apparent charges are evaluated. Figure 9 shows the results.

Figure 9: Numbers of AEB at 150 pC average electrical apparent charge

The number of bursts also shows that the acoustic signals created by PD in aged pressboard are more than in the new pressboard.

4.4 Frequency of AE signals at different amounts of PD apparent charges

Due to the different characteristics of the AE sensors, measured AE frequencies are mostly dependent on physical characteristics of the acoustic sensors and it is not possible to find the correct frequency of the acoustic signal by applying Fast Fourier Transform (FFT), Wavelet or other mathematics methods. According to this fact the frequency of the AE signals were evaluated by comparing the average amplitude of AE signals for the two sensors (75 kHz and 150 kHz) at different average PD apparent charges. Figure 10 shows the comparison for new and aged pressboards. The average amplitude in dB increases with increasing electrical PD amplitude in pC for new and aged pressboard. The signal of the 75 kHz sensor increase more than the signal of the 150 kHz sensor with increasing electrical partial discharges. The signal amplitude of the sensors is higher for aged pressboard than for new pressboard. However in aged pressboard the increasing amplitude rate of the AE signals for 75 kHz is less than in new pressboard due to non-linearity of the preamplifier in acoustic sensors at high AE amplitudes. The results allow the conclusion that with increasing electrical apparent charge the frequency of the AE signal decreases.

Figure 10: Comparison between average amplitude in dB of AE signals and average electrical PD apparent charge in pC for two different sensors (150 kHz and 75 kHz) for a) new pressboard and b) aged pressboard
5 CONCLUSION

In this paper, different factors such as AE inception PD, maximum amplitude of AE and the numbers of AEB at definite average electrical apparent charges and time have been measured. The amplitudes of AE signals in aged pressboard are higher than in new pressboards probably because of different factors such as better transmission of AE signals throw aged pressboards or more vibration of aged pressboards during PD due to lower DP and cellular chains of pressboard. It can be concluded that however the difference is not considerable; the probability of detecting PD by acoustic method in aged power transformers is higher than in new transformers. Comparing the amplitude of two different sensors, the frequency of AE signals has been evaluated. Increasing the average (increasing amplitude and number) of PD apparent charges leads to decrease of the frequency of the AE signals. This could be caused by the superposition of different AE reflection signals, which have lower attenuation at lower frequencies.

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7 REFERENCES

[1] IEC 60270, High Voltage Test Techniques, Partial discharge measurements


